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Title: H2 System Presentation

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LANSCE Hydrogen Moderator Overview

For ESS Discussion

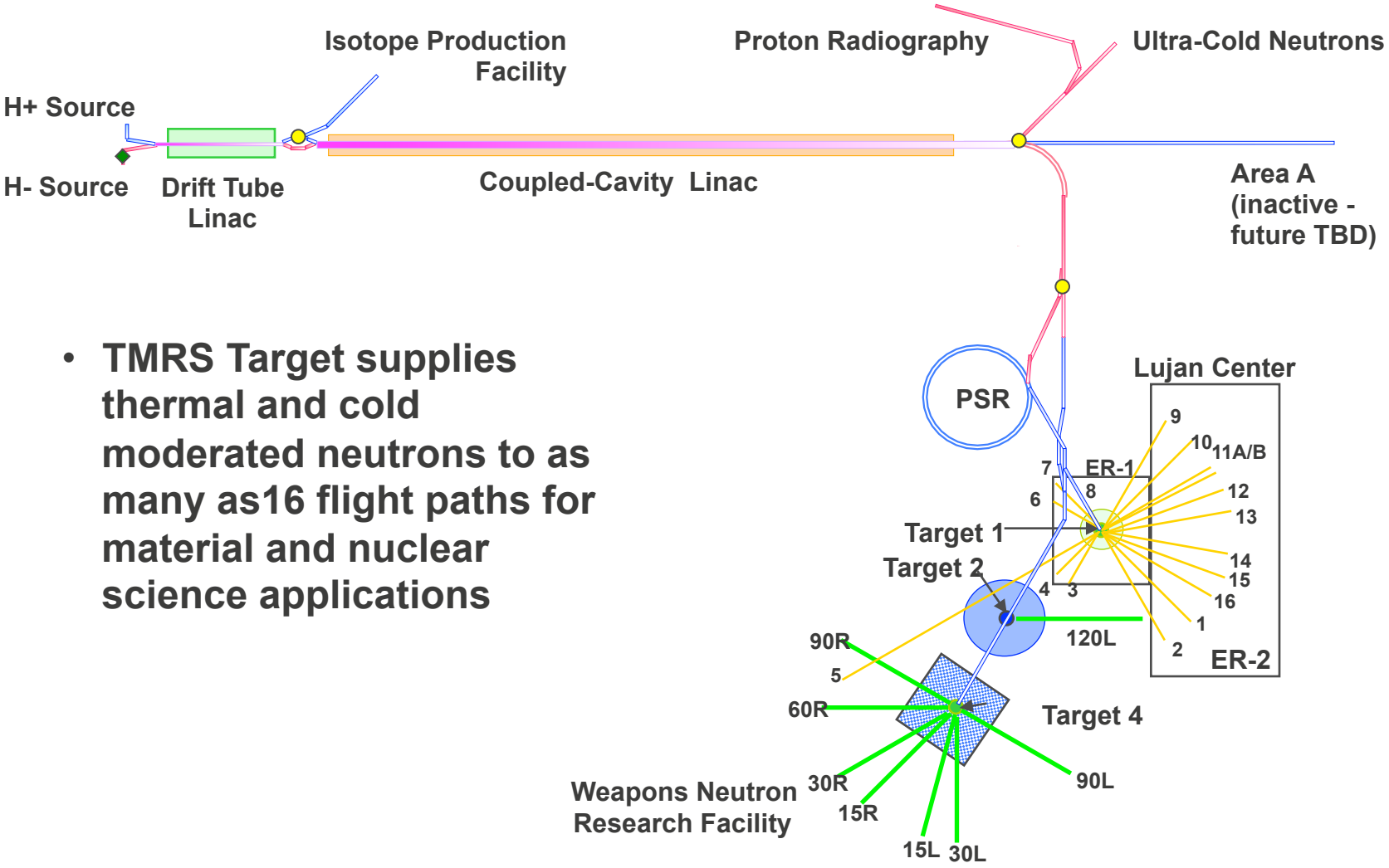
Eron Kerstiens

3/8/18

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

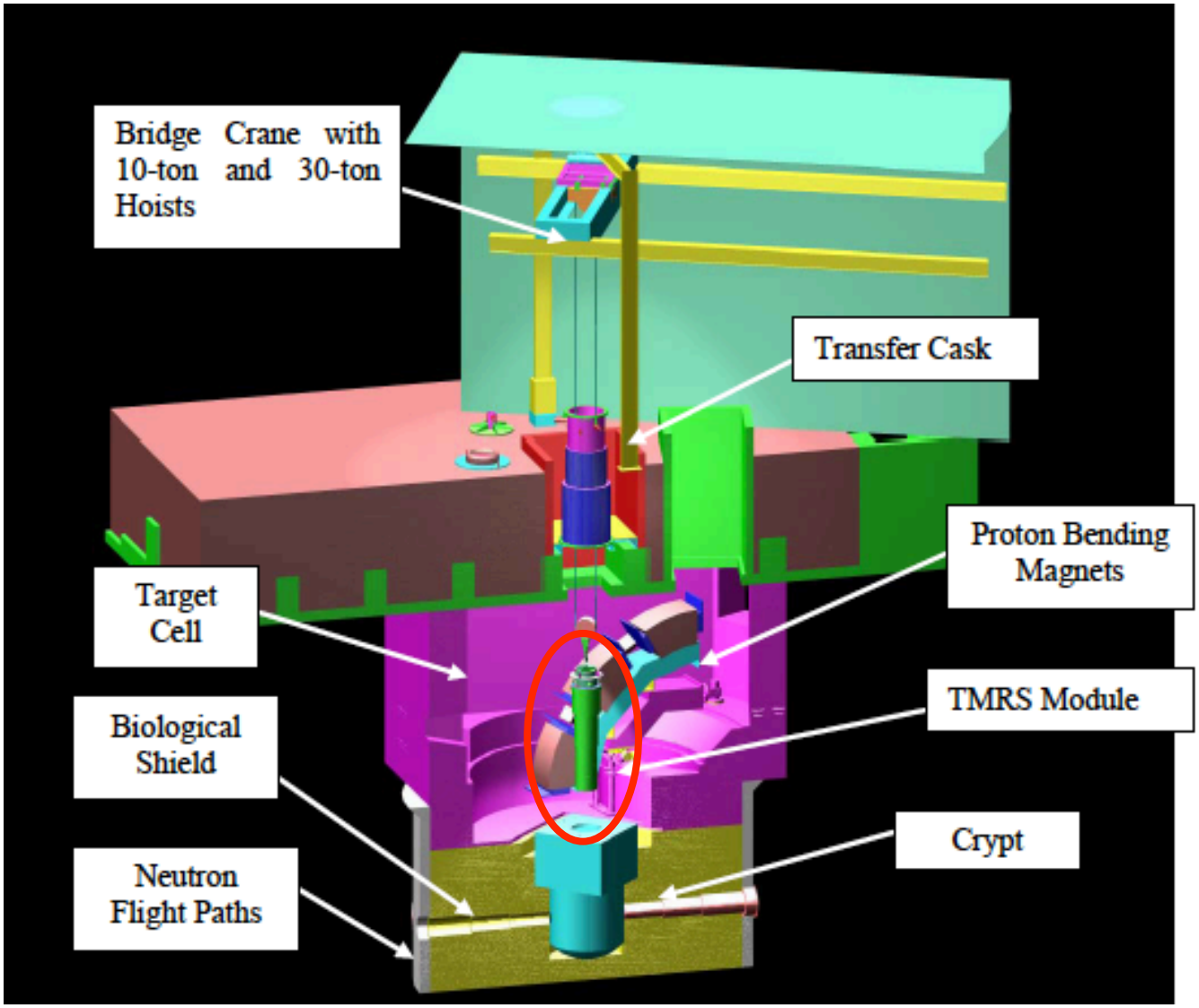
- **Overview of LANSCE Target, Moderator, Reflector**
- **Overview of hydrogen moderator system**
  - Drawings, pictures, equipment
- **Operations**
- **Safety**
- **Helium System**

LANSCE Facility Overview

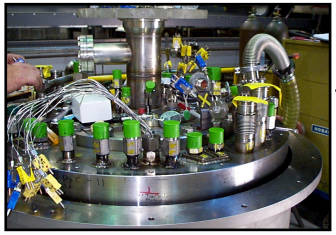


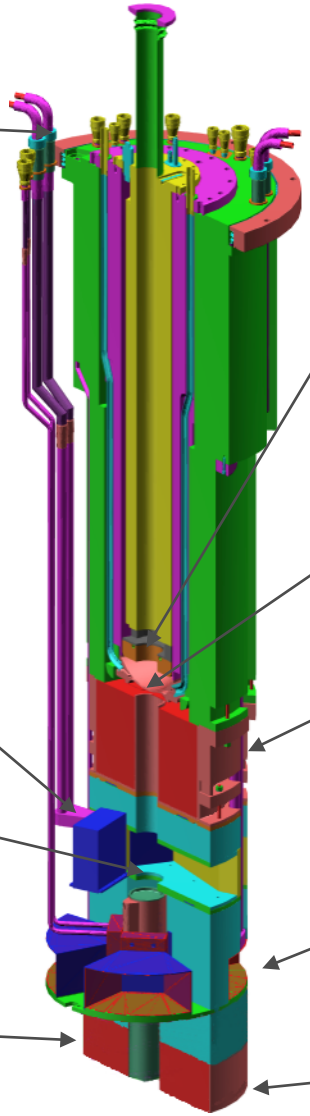
- **TMRS Target supplies thermal and cold moderated neutrons to as many as16 flight paths for material and nuclear science applications**

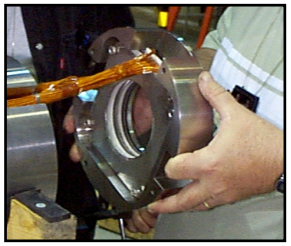
1L Target Cell Layout



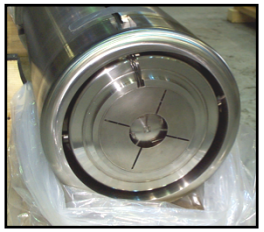
TMRS Mark III Components



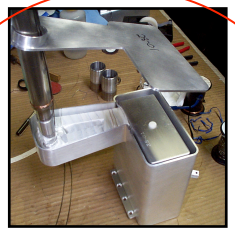




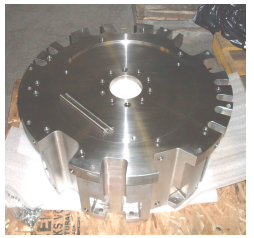
Beam Diagnostic



Beam window and guard ring

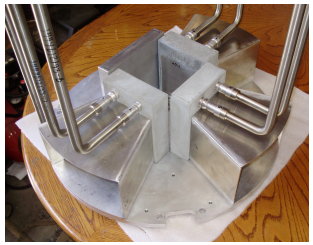


Upper LH_2 Moderator

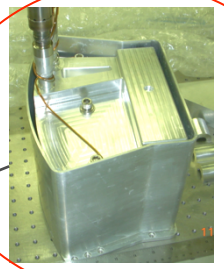


Upper SST reflector

Upper tungsten target



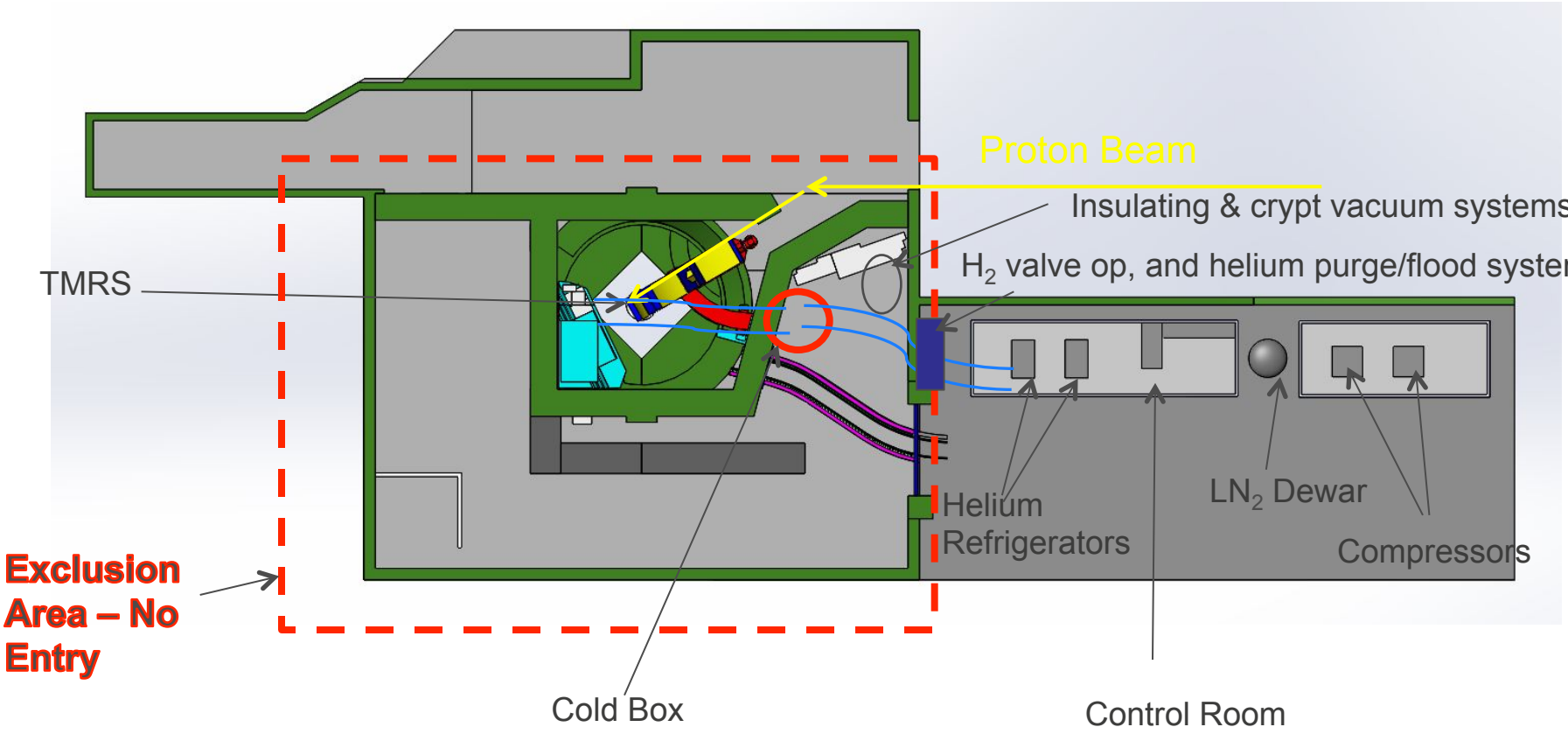
Lower flight path liners and moderators



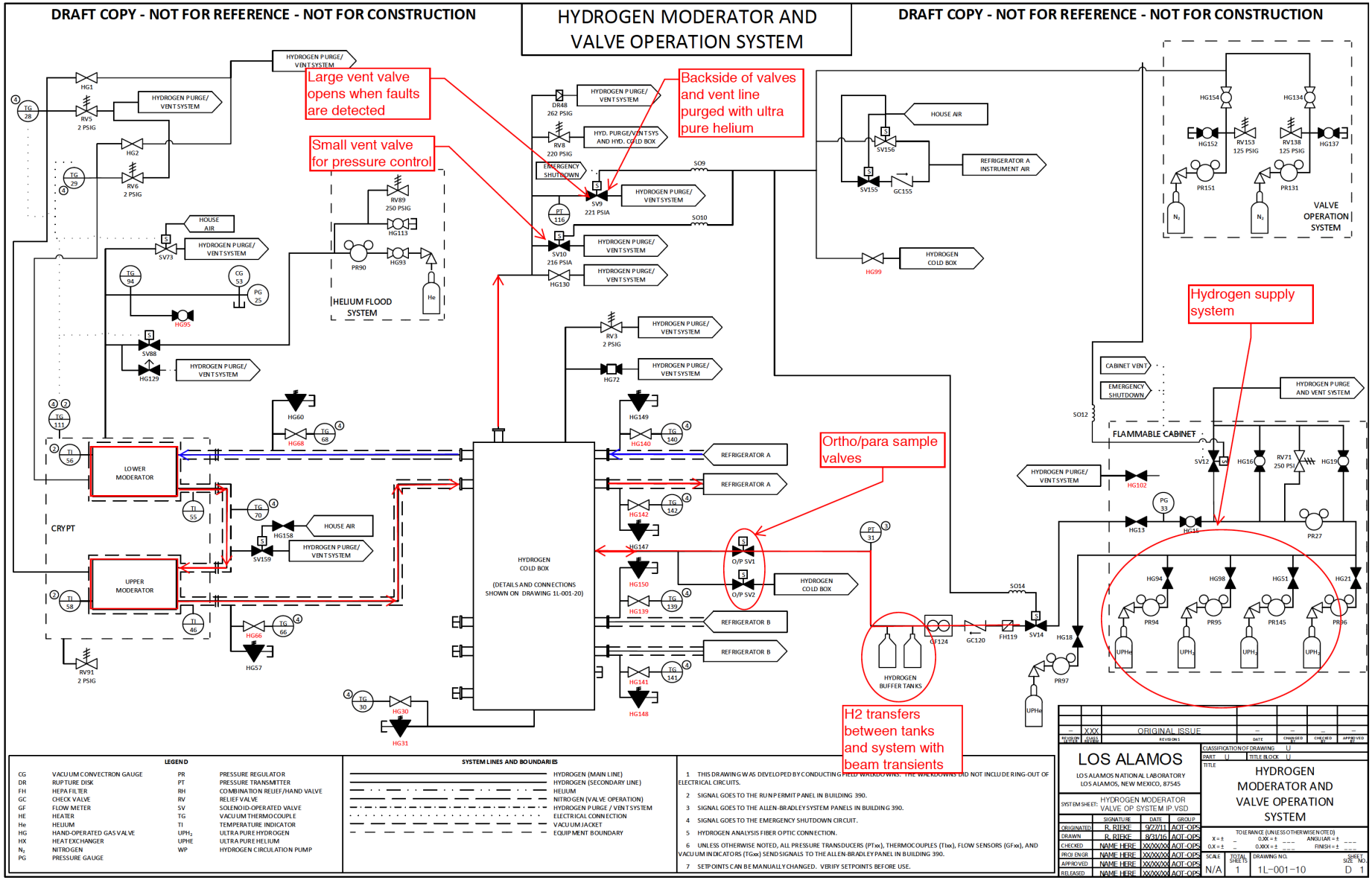
Lower LH_2 Moderator

Lower Be/SST reflector

1L Target Facility Layout



Hydrogen System P&ID



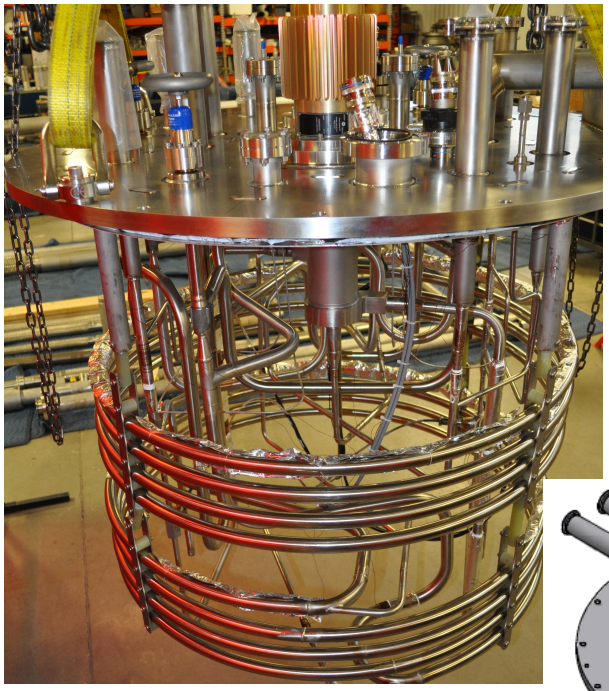
Gas Handling System

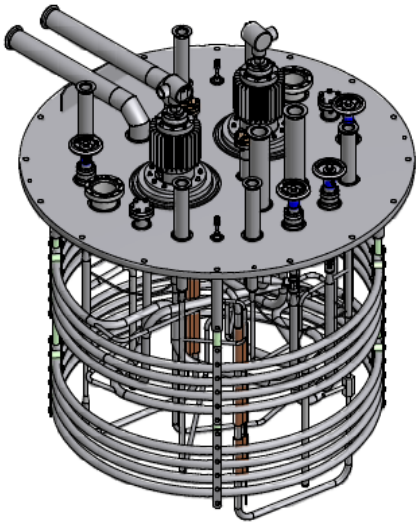
- **Hydrogen cabinet consists of cylinders, regulators, relief valves, hand valves, pneumatic valves all inside of an explosion proof cabinet that is plumbed to atmosphere.**
  - When possible, all tubing/ components are welded. When not possible, VCR fittings are used.

- **Ancillary gas system consists of ultra pure helium for cleaning/ purging the H2 system, nitrogen for valve control, ultra pure helium for vent purge, and ultra pure helium for crypt flood.**

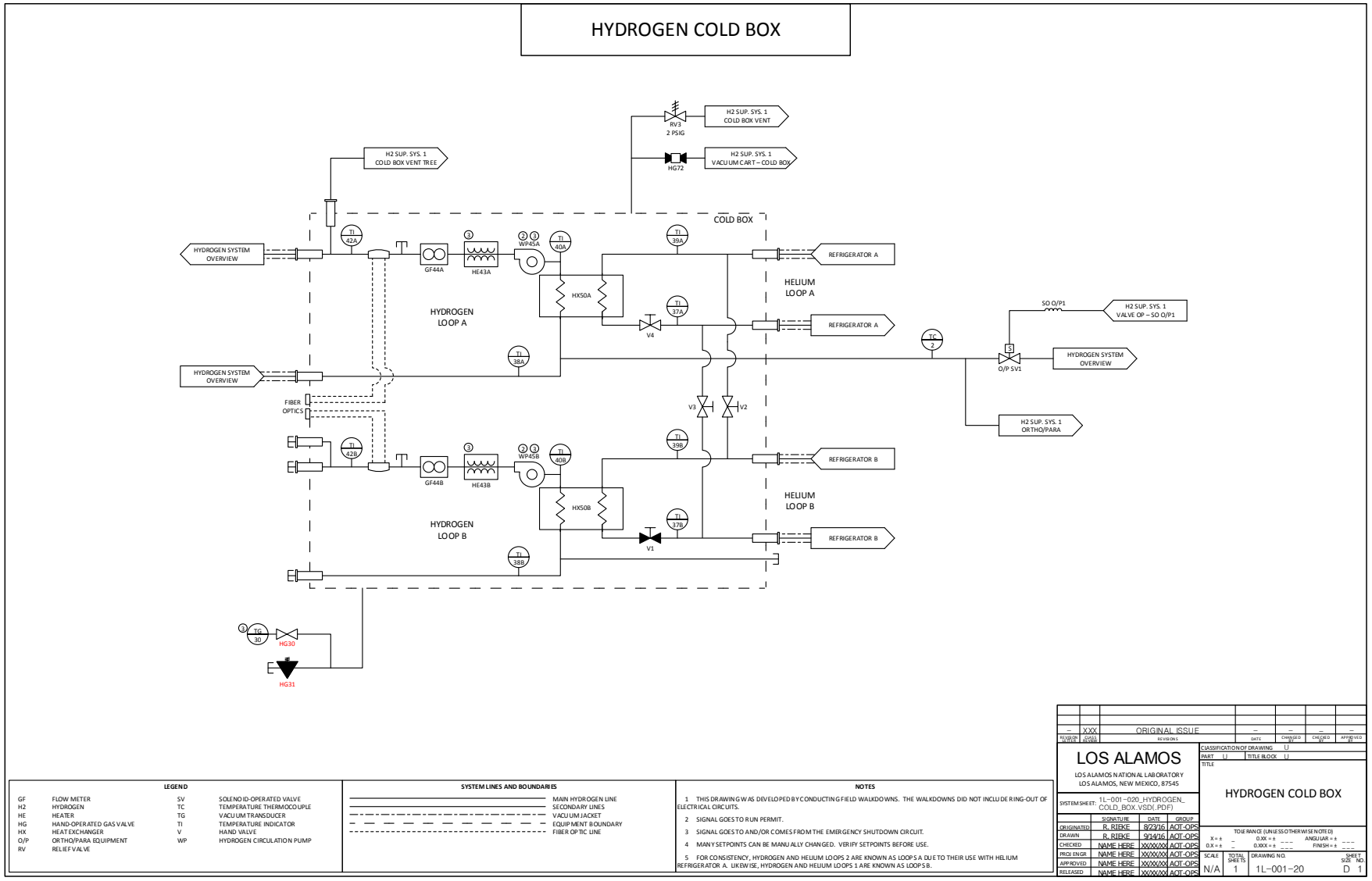
Hydrogen Cold Box – Hydrogen to Helium Heat Exchanger

- **Manufactured by Eden Cryogenics.**
- **Dual loops allows for double the capacity or can serve as a ready spare.**
  - One refrigerator can be plumbed to cool separate H_2 loops or combined to add extra capacity to one H_2 loop.
- **Designed with externally removable Barber-Nichols hydrogen pumps.**
- **Redundant silicone diode and platinum resistor thermometry.**





Hydrogen Cold Box P&ID



LEGEND

GF	FLOW METER	SV	SOLENOID-OPERATED VALVE
H2	HYDROGEN	TC	TEMPERATURE THERMOCOUPLE
HE	HEATER	TG	VACUUM TRANSDUCER
HG	HAND-OPERATED GAS VALVE	TI	TEMPERATURE INDICATOR
HX	HEAT EXCHANGER	V	HAND VALVE
O/P	ORTHO/PARA EQUIPMENT	WP	HYDROGEN CIRCULATION PUMP
RV	RELIEF VALVE		

SYSTEM LINES AND BOUNDARIES

- MAIN HYDROGEN LINE
- SECONDARY LINES
- VACUUM JACKET
- EQUIPMENT BOUNDARY
- FIBER OPTIC LINE

NOTES

1. THIS DRAWING WAS DEVELOPED BY CONDUCTING FIELD WALKDOWNS. THE WALKDOWNS DID NOT INCLUDE RING-OUT OF ELECTRICAL CIRCUITS.
2. SIGNAL GOES TO RUN PERMIT.
3. SIGNAL GOES TO AND/OR COMES FROM THE EMERGENCY SHUTDOWN CIRCUIT.
4. MANY SETPOINTS CAN BE MANUALLY CHANGED. VERIFY SETPOINTS BEFORE USE.
5. FOR CONSISTENCY, HYDROGEN AND HELIUM LOOPS 2 ARE KNOWN AS LOOP'S A' DUE TO THEIR USE WITH HELIUM REFRIGERATOR A. LIKEWISE, HYDROGEN AND HELIUM LOOPS 1 ARE KNOWN AS LOOP'S B.

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SYSTEM SHEET: 1L-001-020_HYDROGEN_COLD_BOX.VSD(.PDF)

CLASSIFICATION OF DRAWING: U
PART: U
TITLE BLOCK: U
TITLE: HYDROGEN COLD BOX

	SIGNATURE	DATE	GROUP
ORIGINATED	R. RIEKE	8/29/16	AOT-OPS
DRAWN	R. RIEKE	9/14/16	AOT-OPS
CHECKED	NAME HERE	XX/XX/XX	AOT-OPS
PROJ ENGR	NAME HERE	XX/XX/XX	AOT-OPS
APPROVED	NAME HERE	XX/XX/XX	AOT-OPS
RELEASED	NAME HERE	XX/XX/XX	AOT-OPS

TOLERANCE (UNLESS OTHERWISE NOTED)
X ± _ 0.XX ± _____ ANGULAR ± _____
0.X ± _ 0.XXX ± _____ FINISH ± _____

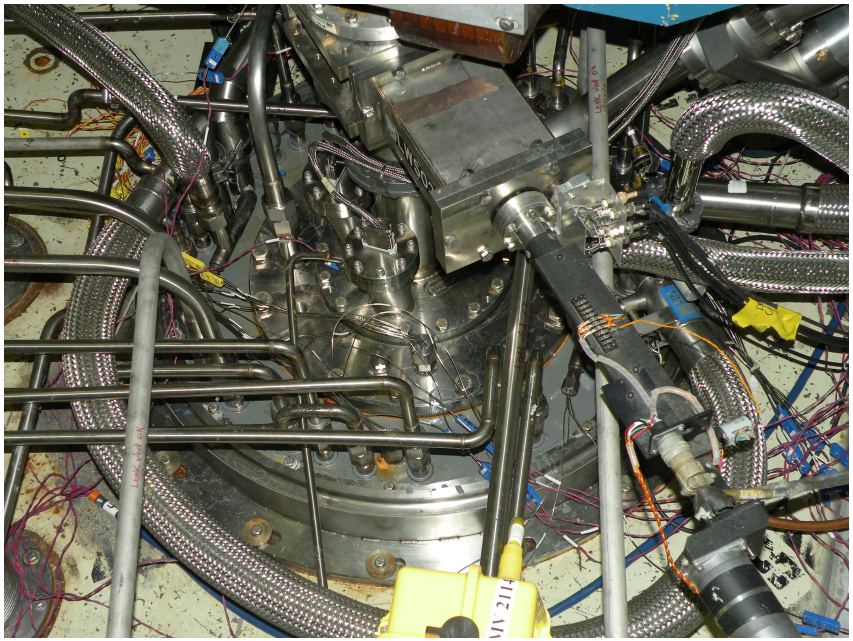
SCALE	TOTAL SHEETS	DRAWING NO.	SHEET SIZE	SHEET NO.
N/A	1	1L-001-20	D	1

Pressure Controls System

- **Vent and relief system consists of 4 valves.**
  - Tier 1 - normally closed throttled pneumatic valve that automatically opens at 216 psia and closes at 211 psa. It's used as the primary system pressure control valve.
  - Tier 2 is a large normally open pneumatic valve that automatically opens at 221 psia and closes at 220 psia. If cycled quickly, pressure usually drops below 200 psia. If left open, system pressure drops to zero rapidly (a couple seconds). This is the emergency shutdown vent valve.
  - Tier 3 is a mechanical relief valve set to 220 psig. Used in the event that control valves fail.
  - Tier 4 is a rupture disk set to 264 psig.
- **Atmosphere side of vent valves is purged with .5 scf/hr ultra pure helium gas at all times.**

Transfer Lines

- 41 feet transfer lines manufactured by PHPK.
- H_2 transfer is through 3/4” OD inner H_2 pressure tubing with a 2” OD single outer vacuum insulation jacket – no helium buffer jacket.
  - If a hydrogen leak occurs in tubing, insulating vacuum interlocks will automatically vent the hydrogen system is vacuum increases to 50 mTorr.
  - For transfer lines under the seal plate, if insulating vacuum increases above 50 mTorr and crypt vacuum increases above 50 Torr, the crypt will be flooded with helium to keep the environment inert.



Hydrogen Operating Parameters

- **Total liquid hydrogen volume is about 12 liters.**
- **Supply temperature is a nominal 20 Kelvin.**
- **System pressure fluctuates depending on beam transients. We aim for a nominal 187 psia (critical pressure of hydrogen to maintain single phase) but beam transients usually fluctuate pressure between 150 and 210 psia.**
- **Mass flow rate is calculated to be about 6 gm/sec.**
  - Installed turbine flow meter has never worked. Previous turbine flow meter also didn't work. Flow rate data obtained from watching thermometry change temperature after beam on/off periods.
- **Beam associated heating is about 2.13 watts/uA.**
  - Residual heat load from the system was once calculated to be about 150 watts.
  - Helium refrigerator performance is the largest variable as it's cooling output can fluctuate by several hundred watts if not running well (intake/ exhaust valves slip and contaminants in helium are the usual culprits)!!

Operations

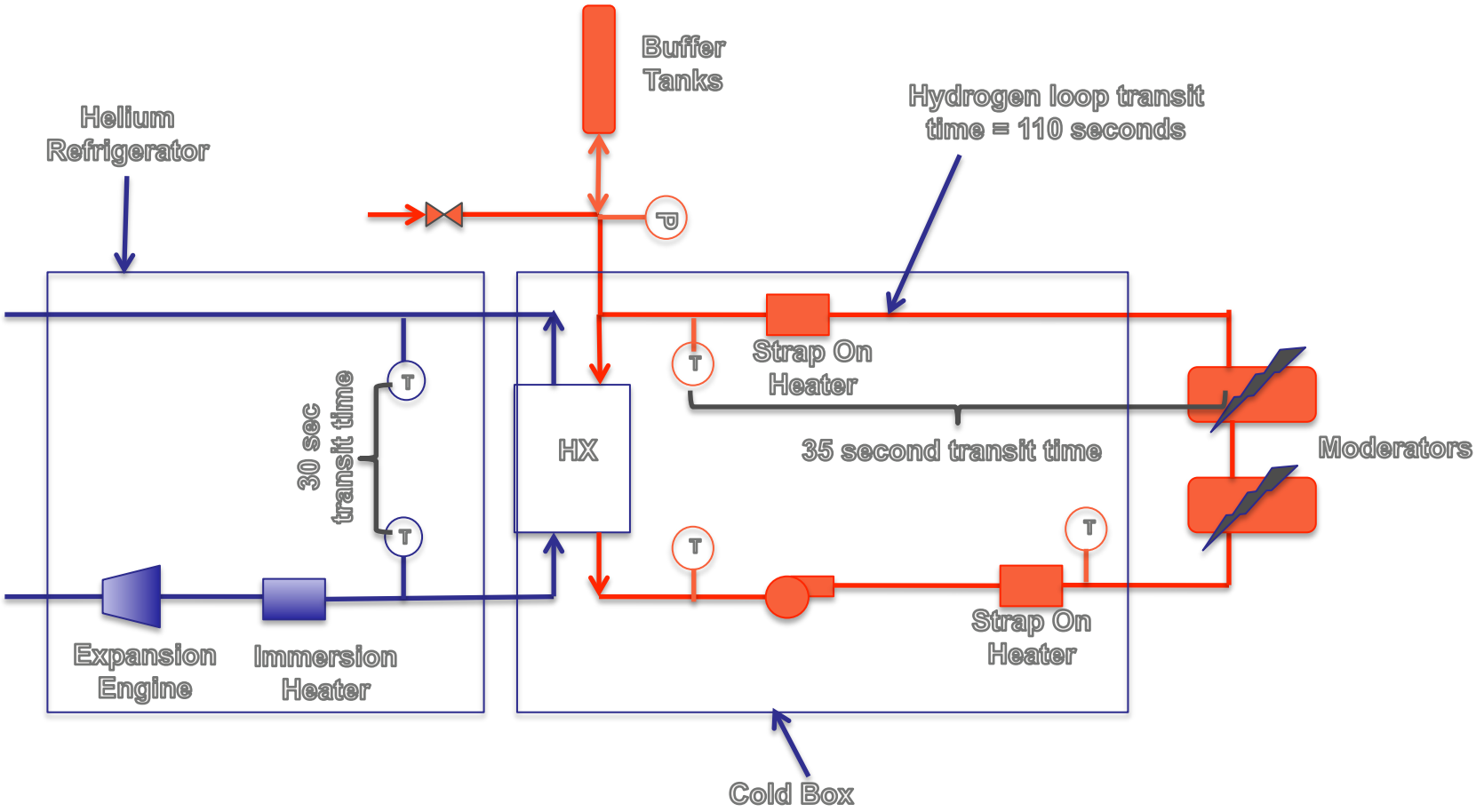
- **Completion of formal qualification program required for operating the system.**
- **Step by step operating procedure for every operational evolution.**
  - Preparations to establish gas operating systems, vacuum systems, pumps, heaters, and safety systems.
  - Startup includes cleanup of the hydrogen loop to remove contaminants.
  - Cooldown and Operations includes steps to condense hydrogen, adding gas, and drawing ortho-para sample.
  - Shutdown includes venting and securing support systems.
  - Abnormal Conditions includes how to respond to an emergency shutdown, alarms, and operational anomalies such as frozen hydrogen.
  - General Procedures specifies how to swap cylinders, purge lines, perform vacuum and pressure tests, and calibrate combustible gas sensors.
  - Interlock Checks tests function of the emergency shutdown system and helium flood system.

Operations

- **Parameters and consumables monitored twice daily during work week and once daily during weekend. EPICS allows for real-time tracking and trending of system performance.**
- **Short but frequent downtime is typically a result of small system vents due to poor pressure control.**
  - New pressure control development is underway
- **Long but infrequent downtime is a result of helium refrigerator problems, contaminated helium or hydrogen gas, or power outages.**
  - Maintenance is performed annually (after about 5000 hours operation)
  - We have had many problem in the past with gas supplies providing contaminated gas.

Heat/Pressure Control

- From beam on to off condition, pressure indication immediately drops but temperature indication takes 35 seconds to respond.



Heat/Pressure Control

- **Hydrogen heaters are metal blocks with 2 500W cartridge strapped to the outside of the SS H_2 tube. Previously used copper blocks but larger thermal mass caused slow response. Currently have 1100 aluminum blocks but thermal contact from aluminum to SS is poor.**
  - Can't use immersion heaters because of ignition source.
- **We are developing a new PID loop that uses predictors such as beam on/off, and pressure to drive the helium heater for a quicker response.**

Hydrogen Safety

- **National Fire Protection Code (NFPC 50C) "Standard for Liquefied H_2 Systems at Consumer Sites" specifies that a hydrogen containing vessel be located 25 feet away from ignition sources and an intake to building ventilation.**
  - The mission and codes have evolved over the years and these requirements weren't initially considered.
- **In 1999 a compliance plan was generated to address the safety concern.**
  - The H_2 heat exchanger (cold box) and associated plumbing is now contained in a non-combustible tent to isolate it from electrical devices and the building air intake.
  - The volume inside the tent is ventilated with an explosion-proof fan that also concentrates the flow past the combustible gas detector. The fan and the gas detectors both include a battery backup power source in the event of a power outage.

Hydrogen Safety Continued

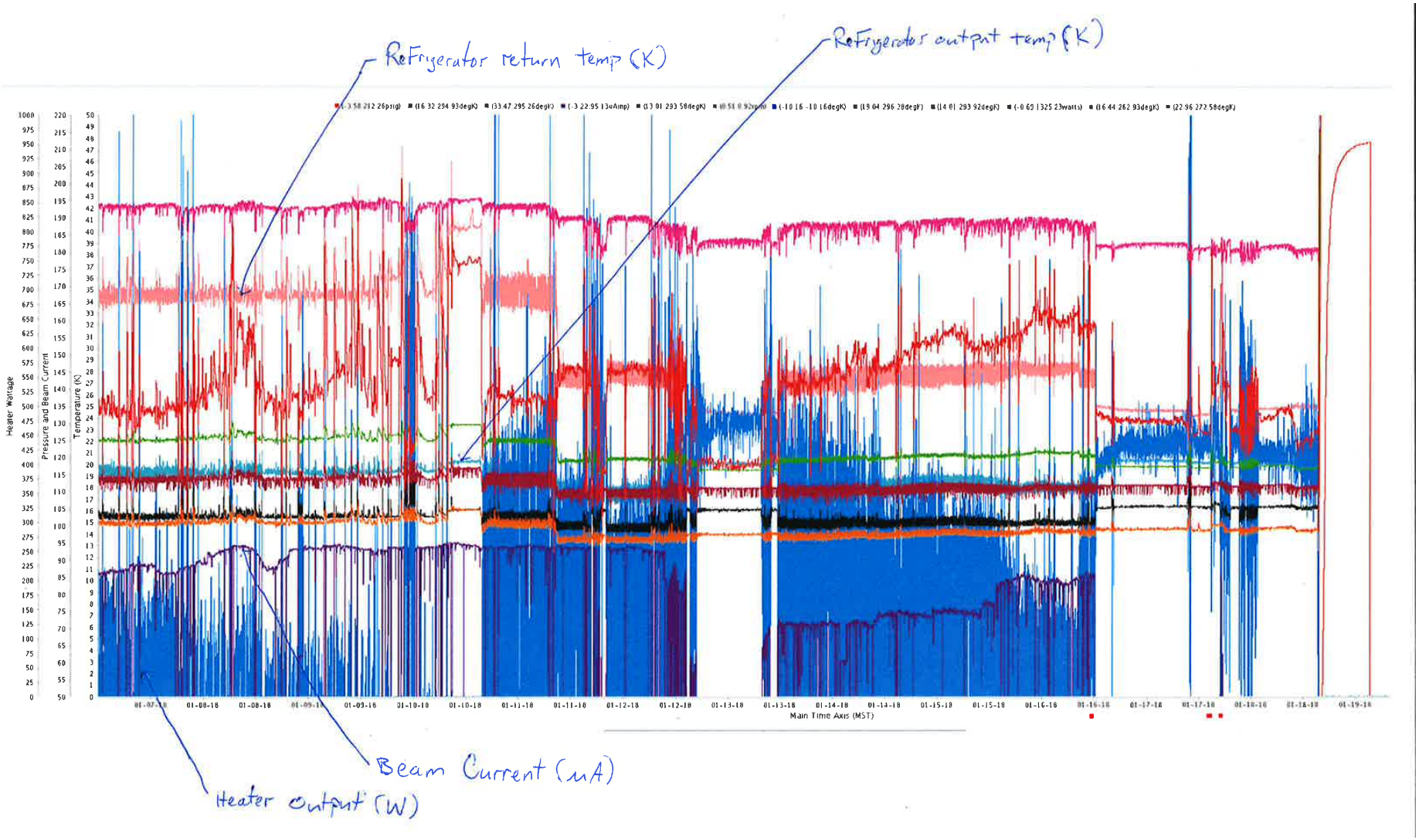
- **A combustible gas detection system continuously monitors ambient air for the presence of a H2 leak from the 1L Hydrogen Moderator System.**
  - Detectors located near non welded joints and ventilation intakes.
  - At 25% of the LEL, the hydrogen moderator system will automatically SCRAM, which vents the H2 gas in the system through a dedicated vent, shut off the heater and circulator, activate the service area evacuation alarm, and turn off the proton beam.
  - Designed to meet the requirements of “explosion proof” Class I, Groups A, B, C, and D, Division 1, as specified by the NEC.
  - Hydrogen detection to SCRAM circuitry all safety rated relays; no software. A hardware based system eliminates the need for a software QA program.
- **Our system was a complete retrofit to adapt to changing mission and codes.**
  - Lessons learned –it’s tough to predict future mission and code changes so plan in a little wiggle room, if possible.

- **Lesson learned – retrofitting is hard. It hard to predict future mission**

Helium System Overview

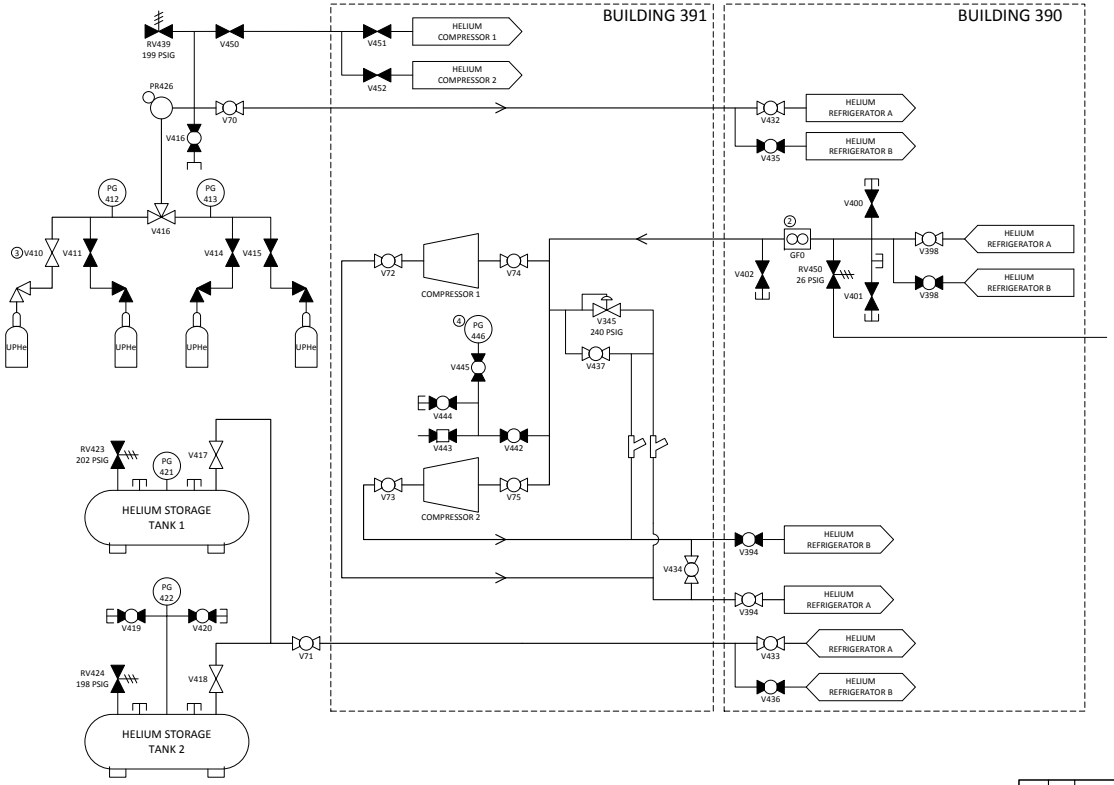
- **Helium gas is compressed and delivered to the refrigerator at approximately 240 psig (16.5 bar)**
- **Gas is cooled in vacuum insulated refrigerator by:**
  - Liquid nitrogen precooling
  - Heat transfer in the main heat exchanger
  - Two expansion engines
- **Cold helium gas exits the refrigerator at about 18 Kelvin and 3 psig (.2 bar) to provide about 900 watts of cooling for the hydrogen system.**
- **Major equipment (all located outside of the exclusion area)**
  - Two Linde LR1620S Helium Gas Refrigerators (one is a spare)
  - Two Linde RS Helium Compressors
  - Supply and return vacuum insulated helium transfer lines fabricated by PHPK each 12 meters long.
- **Instrumentation**
  - Silicone diode thermometry, pressure transducers, and heater current output are used to monitor system performance.

Example of Changing Refrigerator Performance



Helium System P&ID

HELIUM SYSTEM OVERVIEW



LEGEND

GF	MASS FLOW	RV	RELIEF VALVE
PG	PRESSURE GAUGE	UPHe	ULTRA PURE HELIUM
PR	PRESSURE REGULATOR	V	VALVE

SYSTEM LINES AND BOUNDARIES

- HELIUM (MAIN LINE)
- HELIUM (SECONDARY LINE)
- BUILDING BOUNDARY

NOTES

1. THIS DRAWING WAS DEVELOPED BY CONDUCTING FIELD WALKDOWNS. THE WALKDOWNS DID NOT INCLUDE VERIFICATION OF ELECTRICAL CIRCUITS.
2. COMPONENT PROVIDES AN INTERLOCK TO THE RUN PERMIT SYSTEM.
3. LEFT BOTTLE AND V410 ARE SHOWN IN SERVICE ONLY TO SHOW A FLOWPATH. ANY BOTTLE AND ASSOCIATED ISOLATION VALVE ON THIS MANIFOLD MAY BE REPOSITIONED AT ANY TIME AT THE OPERATOR'S DISCRETION.
4. GAUGE IS NOT PERMANENTLY INSTALLED AND MAY BE REMOVED.

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SYSTEM SHEET: 1L-001-009_HELIUM_SYSTEM_OVERVIEW.VSD(.PDF)

CLASSIFICATION OF DRAWING: U
PART: U TITLE BLOCK: U

TITLE: HELIUM SYSTEM OVERVIEW

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DRAWN	R. RIEKE	7/7/16	AOT-OPS
CHECKED	MCCORMICK	1/12/16	AOT-OPS
PROJ ENGR	EDDLEMAN	XX/XX/XX	AOT-OPS
APPROVED	EDDLEMAN	XX/XX/XX	AOT-OPS
RELEASED	KERSTIENS	XX/XX/XX	AOT-OPS

TOLERANCE (UNLESS OTHERWISE NOTED)
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